PANDA: capturing fast dynamics of interfacial surfactant loading

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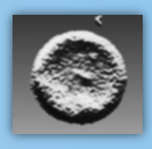
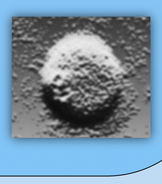
1. Introduction: Capture interfacial dynamics of surfactants

Surfactants are important in:
- Household - industrial processes - …
- biological[1] and microorganism related studies[2].

Here we study their influence on drying droplets, undergoing the coffee ring effect, via microscopy and pendant drops analysis.



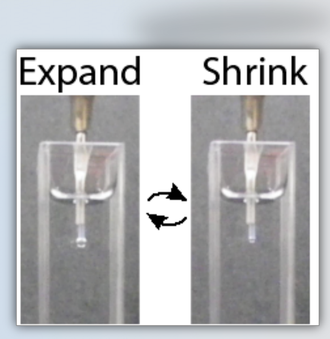
Coffee ring effect of bacterial colony

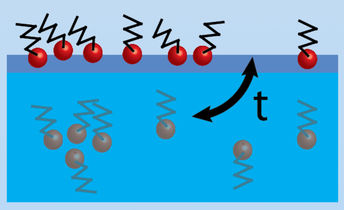


Inhibition of coffee ring by biosurfactant producing bacteria.

2. Methods: Pendant drops

Pendant drop measurement: a droplet is imaged and its contour is fitted. This shape informs about the surface tension by the xenotropic surface active molecules.

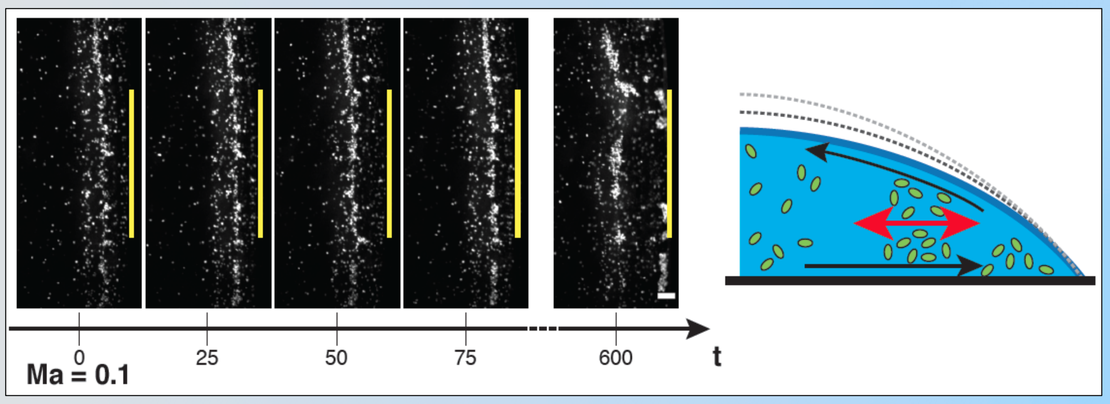




Dynamical measurements by increasing volume (interface) yet is limited by inertia. Here we reverse the phases to improve the temporal resolution. This to probe dynamics of surfactant ad- and desorption at interfaces. **PANDA** or **P**ressure **A**ssisted **N**ucleation of a **D**roplet of **A**ir (up to 20 Hz).

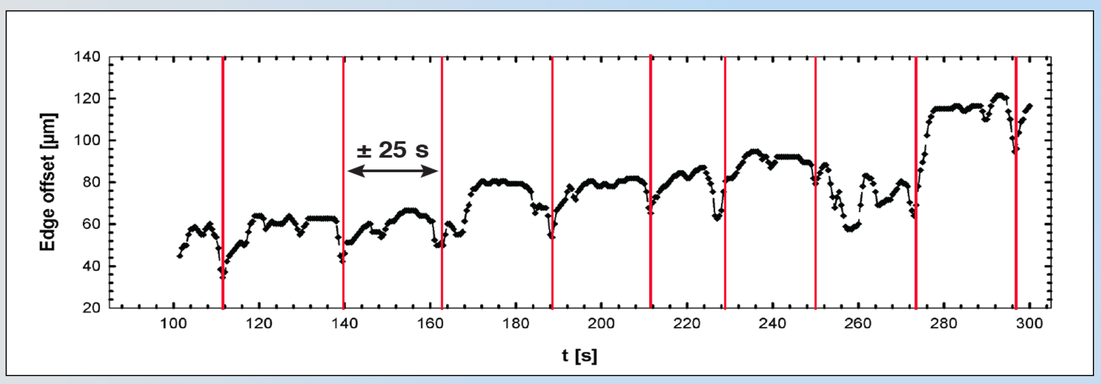
3. Fast confocal flow study of bacteria

Furthermore, a fast confocal is used with tracers (bacteria and nanoparticles), to study the flow in surfactant loaded droplets.



The bacterial front oscillates periodically compared to the droplet's nonmoving pinned contact line. Left, time axis (in s), 30 µm white scale bar and contact line in yellow. Right, a side profilesketch of the oscillation.

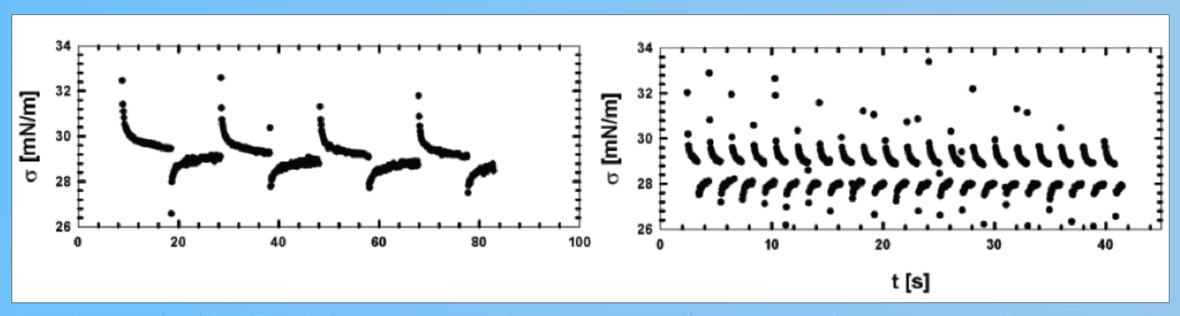
Droplets, loaded with different commercial and bio-surfactants, their internal flow was visualised[2]. Astonishingly we observed (above CMC), time and concentration depending properties influencing the internal flow and the deposition pattern in evaporating droplets.



Time evolution of coffee ring effect at the contact line of a surfactant loaded droplet were the bacterial front oscillates periodically (25 s or 0.04 Hz) compared to the droplets pinned contact line (edge offset, in µm).

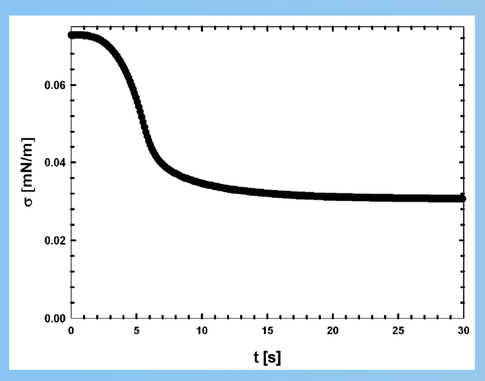
4. PANDA study of (bio)surfactants

Investigation of multiple surfactants and biosurfactant (rhamnolipids). In our case the recurrent time scale of the microscopy study was proven to be the loading of molecules to the interface.



At the left (0,05 Hz) the steady state surface tension is reached, as in standard test, opposing the too fast oscillating right case (0,5 Hz).

Numerical calculation of surface tension confirms dynamics. The initially empty interface (σ=72.8 mN/m) becomes saturated (σ=31 mN/m) after ca. 20 to 25 s.



By a systematic PANDA study of varying concentrations and surfactant types we could conclude that there is a limiting time scale for surfactant loading of the interface, dependent on the molecular properties of the surfactant.

5. Conclusion: surfactant induced Maragoni force and fast surfactant loading of interface

We improved the pendant drop, nicknamed PANDA, via inversion of the phases (air-liquid). This allowed faster oscillating interfaces and a tenfold gain in temporal information, as to capture relevant time scales related to surfactant loading of the interface. We studied geometrically equivalent evaporating droplets, which showed an unique internal flow profile due to capillary and surfactant induced Marangoni forces. By PANDA the recurrent time scales of confocal measurements could be related to the surfactant adsorbing on the interface.

References: 1) Hermans, E., Vermant, J. (2014). Soft Matter, 10 (1), 175-186.
2) W. Sempels & R. De Dier et al. (2013) Nature Communications 4,1 757 doi:10.1038/ncomms2746
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